BELLCOMM, INC.

SUBJECT: Results of the Local Scientific Survey Module (LSSM) Design Studies - Case 232

DATE: March 15, 1967

FROM: F. N. Schmidt
D. R. Valley

ABSTRACT

Final reports for the Local Scientific Survey Module (LSSM) design studies were presented at MSFC from January 24 through January 27, 1967. The two competing contractors (Bendix and Boeing) reviewed their respective vehicle designs and presented detailed program plans for delivery of 3 flight articles.

This memorandum discusses the following items which highlight the more prominent differences in design concepts:

1. 4 wheel vs 6 wheel vehicle
2. AC vs DC motors
3. Nutator vs Harmonic Drives
4. Power vs Manual Steering
5. Surveyor Batteries vs New Development
6. Vehicle Weights
7. Portable Life Support System Exchange Station Designs

(NASA-CR-154437) RESULTS OF THE LOCAL SCIENTIFIC SURVEY MODULE (LSSM) DESIGN STUDIES (Bellcomm, Inc.) 11 p

N79-72054

Unclas
00/14 12487

FACILITY FORM 602

[redacted]
(ACCESSION NUMBE[redacted]
11
(PAGES)
2A
(CODE)
CR-83383
(NASA CR OR TMX OR A[redacted]ER)
11
[redacted]EGORY)

[redacted]

BELLCOMM, INC.

SUBJECT: Results of the Local Scientific Survey Module (LSSM) Design Studies - Case 232

DATE: March 15, 1967

FROM: F. N. Schmidt
D. R. Valley

MEMORANDUM FOR FILE

INTRODUCTION

Final reports for the Local Scientific Survey Module (LSSM) studies were presented at MSFC from January 24 through January 27. The two competing contractors (Bendix and Boeing) presented the results of their respective design studies which included cost estimates for a program to deliver three flight articles. Two days were allotted for each contractor, one day for their formal presentation followed by a day for questions and discussion. Since selection of the final contractor is still pending, the cost information is somewhat sensitive and will not be included in this report. Figure 1 and 2 show the two vehicle configurations proposed, and Figure 3 lists the design criteria used. The following discussion is intended to highlight and comment on the more prominent differences in the two design concepts.

MOBILITY SUBSYSTEM CONSIDERATIONS

As shown in Figures 1 and 2, a 4 wheel and a 6 wheel vehicle have been proposed (all wheels powered). The following performance numbers afford a reasonable comparison of the relative capabilities of the two vehicles and their relation to the basic design criteria.

	4-WHEEL (BENDIX)	6-WHEEL (BOEING)	DESIGN CRITERIA
SPEED			
ELMS[1] Model (km/hr)	9.2	8.1	4.0[2]
ENERGY CONSUMPTION			
Per km (avg)(watt-hours)	169	130	--
Recharge After 25 km Sortie (kw-hrs)	5.63	4.53	--
MOBILITY			
Step Height (Obstacle Size)(cm)	47.5	114	32
Crevice Width (cm)	95	124	51
Turning Radius (m)	10	5.75	--

[redacted]

Many other performance numbers were presented; however, those shown above seem to afford the best common ground for comparison purposes. Except for a slight margin in speed capability, the 6 wheel vehicle seems to offer better performance, but it should be noted that both vehicles exceed the applicable design criteria specifications shown. Perhaps the most important consideration is the lower energy requirements shown for the 6 wheel vehicle. The difference seems quite significant, and it would be interesting to compare the above data with the test data developed with the Mobility Test Article[3] (MTA) program. The 4 wheel vehicle configuration (Fig. 1) offers a more accessible cargo platform (3 sides accessible) and thus some performance advantage for scientific work.

AC VS DC DRIVE MOTORS

The 6 wheel vehicle incorporates AC induction motors to drive each wheel, which requires the use of inverters to convert the battery supply. Motor speed and torque control are accomplished by varying the voltage and frequency of the supply to the motors. The major advantages claimed were:

1. The AC induction motor (squirrel cage) by virtue of its simplicity is more rugged and reliable

2. The AC motors have a higher maximum operating temperature and produce less heat

3. A significant amount of heat generated in DC motors is in the rotating armature which is difficult to cool.

On the other hand, the 4 wheel vehicle employs DC motors and a simple 2 step controller. The main arguments here were:

1. No conversion of battery energy required

2. Simpler control system

3. Back-up available by jumpering directly from battery to motors.

Both sets of arguments have their virtues; however, there seemed to be some question about the simple 2-step controller proposed by Bendix. MSFC people recently conducted a 1/6 "g" test in a KC-135 with a similar sized vehicle and had trouble with wheel slippage (likened to driving on ice). Because of this experience, they feel the need for a smooth continuous speed control rather than stepped, especially in the lower speed range. The people involved in the KC-135 tests felt very strongly about this, and may impose requirements for a more complex throttle control system on the Bendix vehicle.

NUTATOR VS HARMONIC WHEEL DRIVE SYSTEMS

The Bendix vehicle incorporates a nutator drive system while Boeing uses the harmonic drive concept. Both drive systems provide a means of high gear reduction plus allowing the high speed components to be hermetically sealed. Boeing's presentation did not include the drive system; however, in answer to questions on the second day, General Motors (Boeing's subcontractor) indicated that the harmonic drive was carried over from earlier MOLAB studies and indicated such advantages as less gear tooth loading, more balanced load conditions, and more advanced state of the art along with the availability of test data.

Bendix, on the other hand, presented a very comprehensive evaluation of the two drive systems. The nutator drive seems to offer some very definite advantages especially with regard to lubrication. Comparisons of these two drive systems are available in the final reports. Further evaluation of the drive systems is presently underway in the LSSM Wheel and Drive System Test Program being conducted by General Motors, and a limited nutator test program recently initiated with Bendix. It should be noted that each of the contractors stated the capability of incorporating either of the drive systems into their designs.

STEERING

The Boeing 6 wheel vehicle has a significantly shorter turning radius (5.75 meters vs 10 meters) which could be a definite operational advantage. This is the result of a shorter vehicle and use of both front and rear wheel steering, which is accomplished manually. Bendix indicated that, if necessary, a shorter radius could be obtained by modest changes to their design. Four wheel steering could also be employed, but with greater modifications required. Bendix has provided power steering with a manual back-up capability. They feel that power steering gives better performance, provides for greater growth potential, and eases the astronaut's work load. Either vehicle could be designed for manual or power steering without major change.

VEHICLE WEIGHT

Each vehicle meets the design criteria for a 1000 lb vehicle (less crew and cargo). Boeing claimed a 6% allowance for design contingencies while Bendix allowed 13%. Design criteria further specified a 2000 lbs operational vehicle (includes 1000 lbs for crew and cargo). To provide some growth potential, the Bendix design incorporated sufficient structure, power, suspension, wheel stiffness, etc. to enable an operational weight up to 2400 lbs.

POWER SYSTEM

The Boeing vehicle uses 4 Surveyor batteries primarily because they are already qualified for operation in the lunar environment and would require very little development work for LSSM applications.

Bendix proposed development of a new, dry charge type battery which would be optimized for the LSSM duty cycles. They investigated Surveyor batteries but had some reservations due to the difference in duty cycles imposed by Surveyor and the LSSM. Surveyor requires light discharge and charge rates while the LSSM's duty cycle involves much heavier demands.

Initially, Bendix extrapolated some battery capacity vs discharge rate data received from the supplier (Electric Storage Battery). The extrapolated data indicated that their vehicle's energy demands would exceed the 60% depth of discharge criteria specified, even if 5 Surveyor batteries were used. Bendix then verified these results by running their own tests on a Surveyor battery and thus ruled out their use.

The Surveyor battery tests conducted by Bendix raise some doubts about the battery's application to either vehicle. The results, however, are based on the lower limit of the battery operating temperature range (40°F - 100°F) as assumed by Bendix. Boeing, on the basis of their thermal analysis of battery operation indicates temperature limits between 60°F and 125°F. The 20° difference in lower temperature limit would make a substantial difference in the battery capacity. This, coupled with the lower energy requirements of the Boeing Vehicle, makes their application of the Surveyor battery more acceptable.

The Bendix tests also tried to establish the recharge time required for the Surveyor battery. This is another suspect area because the battery was designed for a 1 ampere recharge current. The battery drain imposed by the LSSM plus the 8 hour recharge time specified in the design criteria indicates a 5 ampere charging current requirement. The test battery used by Bendix reached the recharge cut-off voltage (1.95 volts/cell) before sufficient energy could be returned to the battery.

Bendix didn't feel that this test was conclusive, however, since the battery tested had previously been submitted to several deep discharge cycles.

Perhaps some LSSM duty cycle simulation type tests would be in order to clarify the Surveyor battery's capacity and required recharge time.

PLSS EXCHANGE STATION

Each vehicle is required to carry two spare portable life support systems (PLSS) and to provide a PLSS exchange station. The spare PLSS associated with Boeing's exchange station is stowed under the drivers seat in a drawer-like compartment. The other spare unit is stowed in the rear of the vehicle. The drawer must be pulled out and the PLSS unit pivoted to a vertical position before the exchange can take place.

The Bendix exchange station consists of a simple swivel stand mounted on the left side of the vehicle. Two PLSS units can be carried back-to-back thus providing more convenient stowage. The Bendix system also appears to give better access for the exchange, especially for emergency procedures. It seems a little dangerous to depend on a sliding drawer type access to so crucial a unit when you think of the extremely rugged terrain these vehicles are designed to negotiate.

GENERAL

Discussion concerning the resources plan indicated that both contractors had the detailed planning well in hand and each exhibited adequate facilities for producing a qualified vehicle. The most notable difference was a greater diversification in Boeing's plan. General Motors is subcontracted for the mobility subsystem. This involved their Defense Research Laboratories in Santa Barbara, California for the design development work, and the Allis Chalmers - Electronics division in Milwaukee, Wisconsin for manufacturing. Boeing will then assemble and test the vehicle in their facilities at Kent, Washington. Boeing pointed out their overall responsibility for the final product, and monitoring of all program phases seemed well incorporated into the organizational charts presented. This type of program would inherently require a good deal of coordination effort. The Bendix operation, on the other hand, is almost an "in-house" type of effort with the exception of the crew station subsystem being subcontracted to Lockheed.

FUTURE PLANS

Current planning calls for the selection of a single contractor within the next four months. Phase C of the detailed design phase will then be initiated in July or August with the selected contractor. During this phase the contractor will develop the performance and detailed end item specifications and engineering drawings for a final selected NASA vehicle configuration. This phase is presently scheduled to last approximately 9 months. Phase D, or the development phase, would then be initiated with first delivery of a production LSSM approximately 33 months later.

F. N. Schmidt / CJB

F. N. Schmidt

D. R. Valley

D. R. Valley

1012/$^{FNS}_{DRV}$/dmc

Attachments
Figures 1-3

Copy to
Messrs:
D. A. Beattie - NASA/MTL
W. C. Beckwith - NASA/MTP
B. Campbell - NASA/MTL
H. Cohen - NASA/MLR
P. E. Culbertson - NASA/MTL
J. H. Disher - NASA/MLD
F. P. Dixon - NASA/MTY
L. K. Fero - NASA/MLV
J. P. Field - NASA/MLP
E. Z. Gray - NASA/MT
P. Grosz - NASA/MTL
E. W. Hall - NASA/MTS
T. A. Keegan - NASA/MA-2
M. W. Kreuger - NASA/MLA
D. R. Lord - NASA/MTD
M. W. Molloy - NASA/SL
W. T. O'Bryant - NASA/SL
M. J. Raffensperger - NASA/MTE
L. Reiffel - NASA/MA-6
M. Savage - NASA/MT
A. D. Schnyer - NASA/MTV
W. B. Taylor - NASA/MLO
J. H. Turnock - NASA/MA-4

H. E. Gartrell - MSC
R. F. Thompson - MSC

W. B. Shapbell - KSC

G. M. Anderson
J. P. Downs
D. R. Hagner
P. L. Havenstein
W. C. Hittinger
B. T. Howard
D. B. James
K. E. Martersteck
R. K. McFarland
J. Z. Menard
I. D. Nehama
G. T. Orrok
I. M. Ross
T. H. Thomspon
J. M. Tschirgi
R. L. Wagner
All Members Division 101
Department 1023
Central Files
Library

L. L. Bradford - MSFC
R. H. Jackson - MSFC
R. A. Love - MSFC
H. Schaefer - MSFC
R. D. Stewart - MSFC
O. H. Vaughan, Jr. - MSFC

FOOTNOTES

1. Engineering Lunar Model Surface (ELMS) - Preliminary Summary Report by R. L. Mason, W. M. McCombs, and D. C. Cramblit.

2. Minimum speed acceptable on soft soil, zero slope (a portion of the ELMS model).

3. Mobility test articles were built under the MOLAB Study Contracts conducted by Bendix and Boeing.

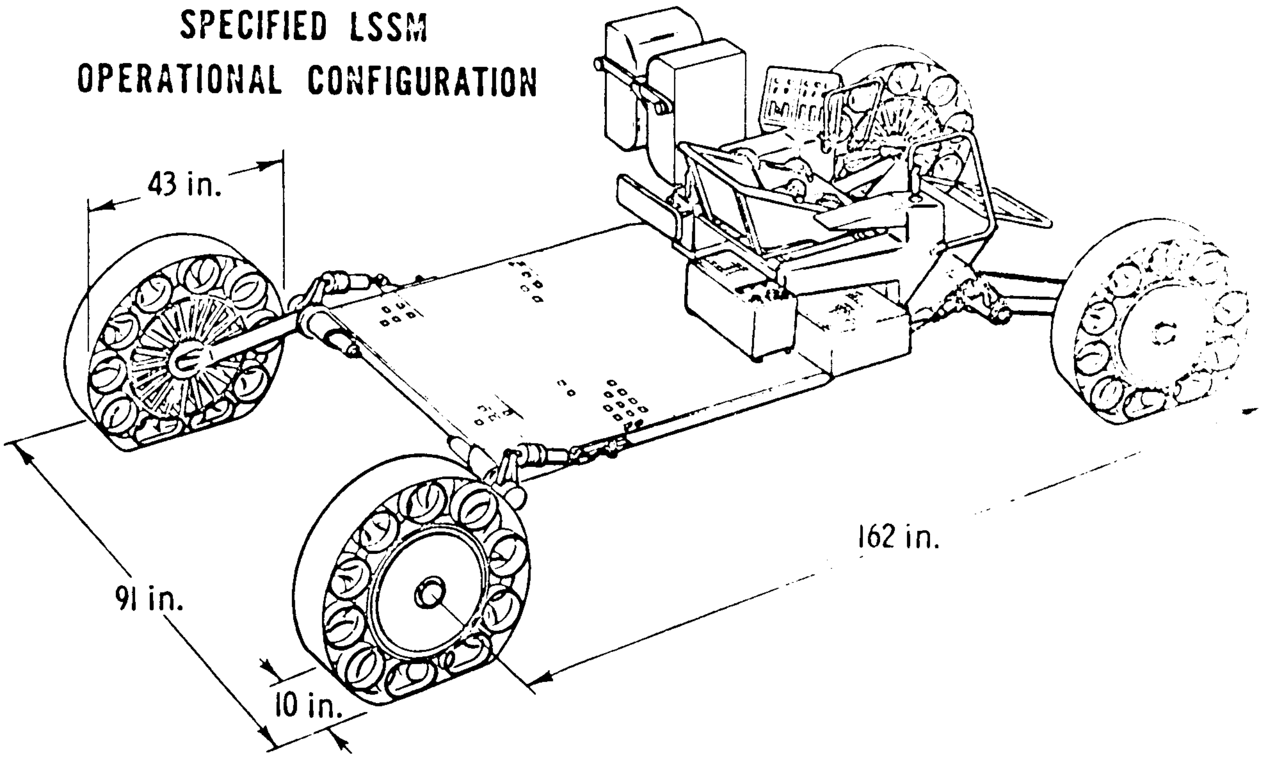

FIGURE 1
(BENDIX)

SPECIFIED LSSM CONFIGURATION DEPLOYED

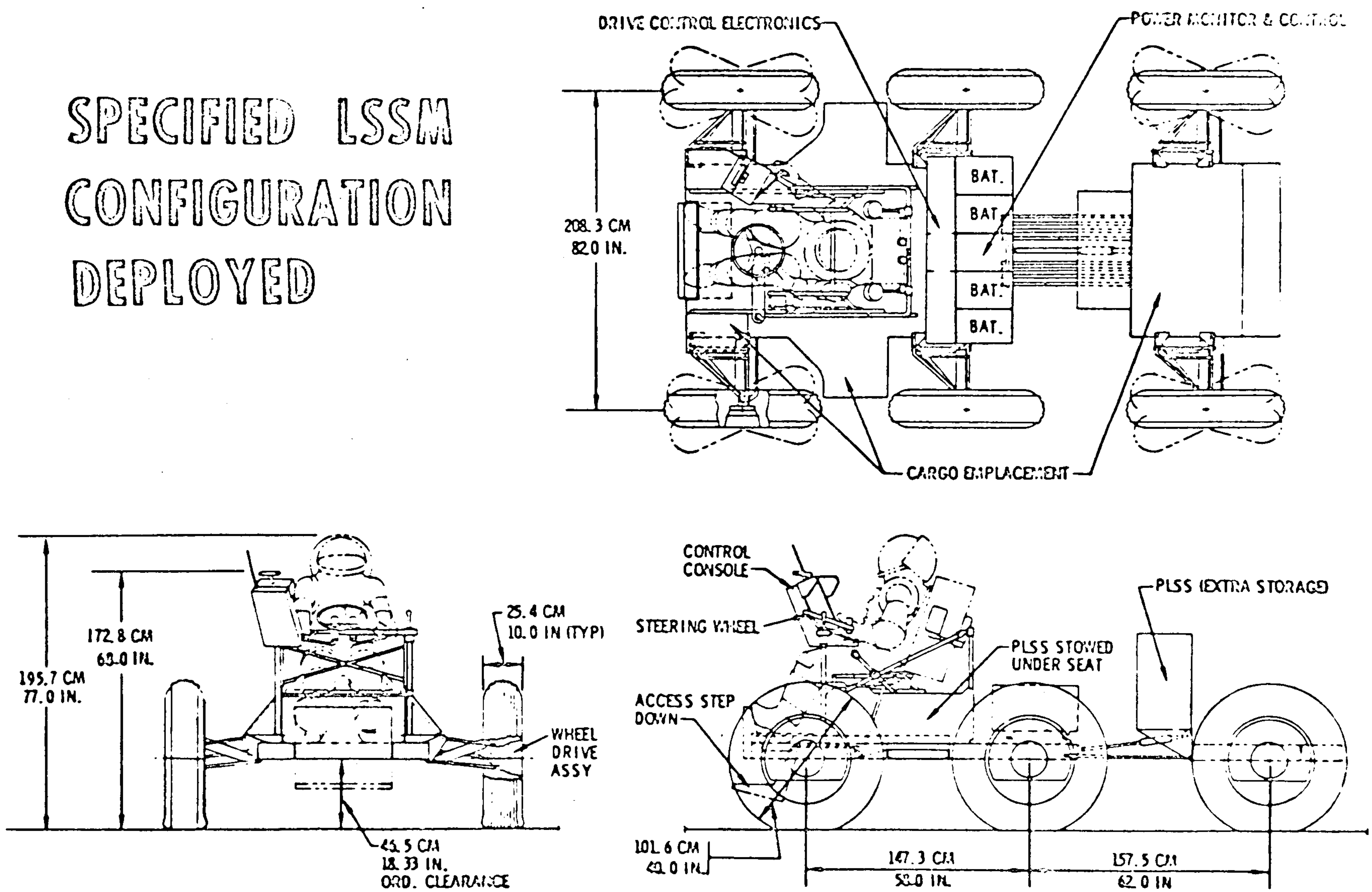

FIGURE 2
(BOEING)

SYSTEM DESIGN CRITERIA

1.	Operating Radius	8 km
2.	Range	25 km sortie, 200 km mission
3.	Minimum Speed	4 km/hr on soft soil, zero slope
4.	Soils and Slopes	ELMS (35^{o} maximum)
5.	Obstacle Crossing Height	32 cm (12 in.) minimum
6.	Crevice Crossing	51 cm (20 in.) minimum
7.	Wheels	Flexible metal with individual drives
8.	Suspension	Required
9.	Vehicle Mass (Without Cargo)	455 kg (1000 lbm) or less
10.	Cargo Mass	318 kg (700 lbm) or less
11.	Crew Accommodation	One suited crewman; second crew-space allotted
12.	Storage Period	90 days
13.	Mission Period	14 days, lunar daytime
14.	Sortie Time	3 to 6 hours
15.	Navigation	Odometer
16.	Life Support	Provisions for two spare PLSS's
17.	Scientific Equip. Accommodation	Open platform
18.	Unloading	Manual
19.	Primary Power	Batteries, 60% maximum discharge

FIGURE 3